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## TITLE OF THE INVENTION

SHEET FEEDING DEVICE, IMAGE READING APPARATUS, AND IMAGE

FORMING APPARATUS

## CROSS-REFERENCE TO RELATED APPLICATIONS

The present application claims priority to Japanese Patent Application Nos. 2003-042283 and 2004-033853 filed in the Japanese Patent Office on February 20, 2003, and on February 10, 2004, the disclosures of which are incorporated by reference herein in their entireties.

## BACKGROUND OF THE INVENTION

### FIELD OF THE INVENTION

The present invention relates to a sheet feeding device and an image reading apparatus for use in an image forming apparatus, such as, a copying machine, a printer, a facsimile machine, or other similar image forming apparatuses that feed and convey a sheet to an image reading position.

### DISCUSSION OF THE RELATED ART

An image forming apparatus, such as, a copying machine, a printer, a facsimile machine, or other similar image forming apparatuses, uses various types of sheet feeding devices that feed original documents having images to be read by an image reading device to an image reading position and convey the original documents toward an image forming device. There is a sheet feeding device of a FRR (Feed & Reverse Roller) type that has been widely used, in which several original documents out of a stack of original documents (hereafter "sheets"), which are stacked on an original document setting table, are picked up

and fed by a sheet pick-up roller, and then fed one by one by a sheet feeding belt and a reverse roller provided downstream of the sheet pick-up roller in the sheet feeding direction.

In the above-described sheet feeding device of an image forming apparatus, for example, a stack of original documents are set on an original document setting table lying face-up so that a user can see the image of the original document. After the original document has been separated from the other original documents, and while it is conveyed to an image reading position, the original document is reversed. As a result, the image of the original document is directed downward at the image reading position and is read by an image reading device located below the original document. The original documents are discharged from the sheet feeding device after their images have been read by the image reading device, and are sequentially stacked such that the front side of each page of the original documents is directed downward. As a result, the original documents are stacked in a correct order.

In a sheet feeding device that feeds original documents to an image reading position, various types of original documents have been used, such as a color copy sheet. In the case of a color original document, silicone oil is often applied onto the surface of the color original document. When the silicone oil is adhered to a sheet pick-up roller and a sheet feeding belt, sheet feeding forces of the sheet pick-up roller and sheet feeding belt decrease as the number of sheets fed by the sheet pick-up roller and sheet feeding belt increases. As a result, a sheet feeding failure, such as, a sheet slip and a sheet jam, typically occurs.

In the sheet feeding device, a reverse roller is provided opposite a sheet feeding belt. When the sheet feeding belt and the reverse roller are driven, the sheet feeding belt and the reverse roller rotate in opposite directions. For example, when the sheet feeding belt feeds the first page of a stack of original documents toward the downstream side in the sheet feeding direction, the reverse roller obstructs the feeding of the second or following pages.

Thus, because of the operation of the sheet feeding belt and the reverse roller, the original documents are fed one by one.

As long as a stack of original documents are set on an original document setting table lying face-up and silicone oil is adhered onto both side surfaces of an original document silicone oil does not adhere to the reverse roller, but adheres to the sheet feeding belt and the sheet pick-up roller. In this condition, the balance is lost between the reverse force (opposite the sheet feeding direction) of the reverse roller and the forward force of the sheet feeding belt. Specifically, the reverse force of the reverse roller exceeds the sheet feeding force of the sheet feeding belt, thereby increasing the slip ratio of the sheets.

In the above-described sheet feeding device, a pair of pull-out rollers (so-called sheet abutment rollers) are provided downstream of the sheet feeding belt in the sheet feeding direction. To reduce the size of the sheet feeding device, the device is configured so that a drive motor is rotated in a forward direction to rotate the sheet pick-up roller and the sheet feeding belt, and the drive motor is rotated in a reverse direction to rotate a pull-out roller. In this configuration, an original document is picked up by the sheet pick-up roller and fed by the sheet feeding belt while the drive motor is rotated in the forward direction, and is then abutted against a nip part of the pull-out rollers in a halt condition while feeding the original document a distance greater than a sheet feeding path to perform a sheet skew correction. In the sheet skew correction, the leading edge of the original document is aligned, and thereby the posture and position of the original document are registered. The sheet feeding distance for abutting the original document against the nip part of the pull-out rollers is set based on information detected by a sensor provided immediately before the pull-out rollers.

Published Japanese patent application No. 10-101238 describes a sheet feeding device for a copy machine in which a sheet pick-up roller contacts a sheet and rotates for picking up and feeding the sheet. An encoder is attached to a rotation shaft of the sheet pick-up roller to

detect a rotational speed of the sheet pick-up roller. If a sheet feeding amount of the sheet pick-up roller changes, the rotational speed and a rotation start timing of the sheet pick-up roller are controlled to maintain a copy speed of the copy machine.

Further, published Japanese patent application No. 6-271149 describes a sheet feeding device in which a time for rotating a sheet pick-up roller is extended in accordance with an extent by which a travel distance of a sheet, which is fed by rotating the sheet pick-up roller during a predetermined time, is less than a required distance. By doing so, the actual travel distance of the sheet fed by the sheet pick-up roller becomes substantially equal to the required distance, so that a sheet jam is prevented.

In the above-described sheet feeding device, the condition of the sheet pick-up roller changes with time. Especially, the decrease of a frictional force between the sheet pick-up roller and a sheet should be considered. For example, such a decrease of the frictional force is caused by debris, such as paper powder and oil, on the sheet pick-up roller. Further, if a stack of original documents are stacked on an original document setting table, a frictional force and an electrostatic absorption between original documents should be considered. These typically cause the decrease of a sheet feeding force in the sheet feeding device using a FRR method, thereby causing a sheet feeding failure.

Moreover, the slip of a color original document to which silicone oil is applied should be considered. Due to the slip of a color original document, the leading edge of the original document may not abut against the nip part of the pull-out roller. As a result, a sheet feeding failure occurs at the pull-out rollers. An oil-less color copying machine has been developed. However, many color copying machines on the market use an oil processing method. As described above, when a color original document having a color image on its front side is fed in the sheet feeding device, a sheet feeding failure, such as, a sheet slip and a sheet jam, typically occur.

When an original document having a tendency to slip (e.g., an original document having a penciled image and a thin sheet) is fed in a sheet feeding device, if a time for rotating a sheet pick-up roller is increased under the condition that the original document slips, the original document may be damaged.

Therefore, it is desirable to provide a sheet feeding device for use in an image reading apparatus or an image forming apparatus, which automatically detects the decrease of a sheet feeding force in the sheet feeding device and prevents the stopping of the sheet feeding operation while reducing an occurrence of a sheet feeding failure.

## SUMMARY OF THE INVENTION

The present invention provides a sheet feeding device. A sheet pick-up device is configured to pick up a first sheet from stacked sheets and to feed the first sheet by contacting the first sheet while rotating. A sheet separating device is configured to separate the first sheet from another sheet fed with the first sheet by the sheet pick-up device. The sheet separating device includes a rotary member configured to feed the first sheet by contacting the first sheet while rotating, and an obstructing member configured to obstruct feeding of the another sheet. A drive device is configured to drive at least one of the sheet pick-up device and the rotary member to rotate. At least one detecting device is configured to detect a leading edge of the first sheet. A control device is configured to control sheet feeding. The control device is configured to change a rotational speed of at least one of the sheet pick-up device and the rotary member based on a detection result of the at least one detecting device and a drive amount of the drive device.

The present invention further provides an image reading apparatus. An image reading device is configured to read an image of an original document at an image reading position. A sheet feeding device is configured to feed the original document to the image reading

position. The sheet feeding device includes a sheet pick-up device configured to pick up a first original document from stacked original documents and to feed the first original document by contacting the first original document while rotating, and a sheet separating device configured to separate the first original document from another document fed with the first original document by the sheet pick-up device. The sheet separating device includes a rotary member configured to feed the first original document by contacting the first original document while rotating, and an obstructing member configured to obstruct feeding of the another document. The sheet feeding device further includes a drive device configured to drive at least one of the sheet pick-up device and the rotary member to rotate, at least one detecting device configured to detect a leading edge of the first original document, and a control device configured to control original document feeding. The control device is configured to change a rotational speed of at least one of the sheet pick-up device and the rotary member based on a detection result of the at least one detecting device and a drive amount of the drive device.

According to another aspect of the present invention, an image forming apparatus includes an image reading device configured to read an image of an original document at an image reading position, an image forming device configured to form the image read by the image reading device, and the sheet feeding device configured to feed the original document to the image reading position.

## BRIEF DESCRIPTION OF THE DRAWINGS

A more complete appreciation of the present invention and many of the attendant advantages thereof will be readily obtained as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings, wherein:

FIG. 1 is a schematic sectional view of an exemplary image forming apparatus according to an embodiment of the present invention;

FIG. 2 is a cross section of a portion of an auto document feeder according to an embodiment of the present invention;

FIG. 3 is a perspective view of a drive system using a sheet feeding motor according to an embodiment of the present invention; FIG. 4 is a perspective view of a drive system using an image reading motor according to an embodiment of the present invention; FIG. 5 is a perspective view of a drive system using a lower reversing motor according to an embodiment of the present invention;

FIG. 6 is a perspective view of a drive system using a sheet discharging motor according to an embodiment of the present invention;

FIG. 7 is a perspective view of a drive system using an upper reversing motor according to an embodiment of the present invention;

FIG. 8 is a block diagram of a control system in the image reading apparatus according to an embodiment of the present invention;

FIGS. 9A through 9J are schematic views showing sheet feeding and conveying operations reading images on both sides of an original document;

FIG. 10 is a flowchart of sheet feeding control operation steps of a controller according to an embodiment of the present invention;

FIGS. 11A and 11B are flowcharts of sheet feeding control operation steps of a controller according to another embodiment of the present invention;

FIG. 12 is a schematic view of a portion of the auto document feeder showing a position of a first slip sensor according to an embodiment of the present invention;

FIG. 13A is a schematic view of a portion of the auto document feeder showing another position of the first slip sensor according to another embodiment of the present invention;

FIG. 13B is a schematic perspective view of a portion of the auto document feeder of FIG. 13A showing a position of a sheet pick-up roller;

FIG. 13C is a schematic perspective view of a portion of the auto document feeder of FIG. 13A showing positions of the first slip sensor and a reverse roller;

FIGS. 14A through 14C are flowcharts of sheet feeding control operation steps of a controller according to another embodiment of the present invention;

FIG. 15 is a schematic view of a portion of the auto document feeder showing positions of the first slip sensor and a second slip sensor according to another embodiment of the present invention;

FIGS. 16A and 16B are flowcharts of sheet feeding control operation steps of a controller according to another embodiment of the present invention;

FIGS. 17A through 17C are flowcharts of sheet feeding control operation steps of a controller according to another embodiment of the present invention;

FIGS. 18A and 18B are flowcharts for displaying a replacement message for the sheet pick-up roller and/or the sheet feeding belt according to another embodiment of the present invention; and

FIG. 19 is an enlarged view of an operation unit and a display unit according to an embodiment of the present invention.

## DESCRIPTION OF THE PREFERRED EMBODIMENTS



Preferred embodiments of the present invention are described in detail referring to the drawings, wherein like reference numerals designate identical or corresponding parts throughout the several views.

FIG. 1 is a schematic sectional view of an exemplary image forming apparatus, such as, an electrophotographic copying machine according to an embodiment of the present invention. The image forming apparatus includes an image reading apparatus 600 that reads an image of an original document, an image forming device 610 that forms images, and a sheet feeding unit 680 including sheet feeding cassettes 640, 650, 660, and 670. In the image reading apparatus 600, an auto document feeder 620 functioning as a sheet feeding device is connected to an upper portion of a main body 200 of the image reading apparatus 600 via connection member, such that the auto document feeder 620 is configured to be opened and closed with respect to the main body 200 of the image reading apparatus 600.

An image carrier, such as a photoreceptor 611, is provided in the image forming device 610. The photoreceptor 611 is driven to rotate in the clockwise direction in FIG. 1. A charging device 612 charges the surface of the photoreceptor 611 with a predetermined polarity. An image writing unit 613 irradiates the surface of the charged photoreceptor 611 with a laser light (L) that is modulated in accordance with image information obtained by the image reading device 600, thereby forming an electrostatic latent image on the surface of the photoreceptor 611. A developing device 614 develops the electrostatic latent image with toner, and forms a toner image. Then, a transfer device 615 transfers the toner image from the photoreceptor 611 to a recording medium (P), such as a sheet, that is fed to a nip part between the photoreceptor 611 and the transfer device 615. After the toner image is transferred from the photoreceptor 611 to the recording medium (P), a cleaning device 616 removes residual toner remaining on the surface of the photoreceptor 611.

The sheet feeding cassettes 640, 650, 660, and 670, which are disposed below the image forming device 610, accommodate recording media (P). The recording medium (P) is fed from one of the sheet feeding cassettes 640, 650, 660, and 670, and receives the toner image transferred from the photoreceptor 611. Subsequently, the toner image is fixed onto the recording medium (P) by heat and pressure while the recording medium (P) passes through a fixing device 617 disposed in the image forming device 610. The recording medium (P) having a fixed toner image is conveyed by a pair of sheet discharging rollers 618 and is discharged and stacked on a sheet discharging tray 690.

FIG. 2 is a cross section of a portion of an auto document feeder according to an embodiment of the present invention. The auto document feeder 620 includes an original document setting section (A), a sheet separating/feeding section (B), a registration section (C), a reverse section (D), an image reading/sheet conveying section (E), a switch-back section (F), an intermediate conveyance section (G), a switch-back section (H), a sheet reversing/discharging section (I), and a sheet stack section (J).

Specifically, an original document 1, which may be set atop a stack of other original documents (not shown), is set in the original document setting section (A). The sheet separating/feeding section (B) is configured to separate the original document 1 from the stack of the original documents set in the original document setting section (A) and to feed the original documents one by one. The registration section (C) registers the surface of the fed original document 1 and conveys the registered original document 1. In the reverse section (D), the conveyed original document 1 is reversed to direct the image side of the original document 1 downward. The image reading/sheet conveying section (E) positions the image of the original document 1 to be read from the lower side of a slit glass 602 while conveying the original document 1. The switch-back section (F) retracts the read original document 1 and reverses front and rear sides of the original document 1. The intermediate

conveyance section (G) is configured to return the original document 1 that has been reversed in the switch-back section (F) to the registration section (C). The switch-back section (H) is configured to temporarily hold the original document 1 after it has passed through the reverse section (D) and the image reading/sheet conveying section (E) in which the image of the rear side of the original document 1 was read. The sheet reversing/discharging section (I) is configured to reverse the original document 1 held in a standby condition in the switch-back section (H), and to discharge the original document 1 from the auto document feeder 620. The sheet stack section (J) is configured to stack and hold the read original documents 1.

Further, as illustrated in FIG. 8, the auto document feeder 620 includes a drive mechanism that drives elements of the auto document feeder 620 for sheet feeding and conveying operations, and a controller 100 that controls the sheet feeding and conveying operations (described below). The switch-back section (F), the intermediate conveyance section (G), the switch-back section (H), and the sheet reversing/discharging section (I) are used when images of the front and rear sides of the original document 1 are read.

The original document 1 or a stack of original documents is set on an original document setting table 2 lying face-up. The stack of original documents is positioned in their width direction (i.e., the direction perpendicular to the sheet feeding direction) by side guide plates (not shown). A set filler 4 rises when the original document 1, or a stack of original documents, is set on the original document setting table 2. An original document set sensor 5 detects by the position of the set filler 4 that the original document 1 is set on the original document setting table 2. The detection result of the original document set sensor 5 is transmitted to a main body control unit 212 (shown in FIG. 8) of the main body 200 of the image reading apparatus 60C which controls operations of the image reading apparatus 600, via an interface (not shown). A reflection type sensor or an actuator type sensor may be used

for a first original document length sensor 34 and second original document length sensor 35 to detect the length of the original documents 1 in the sheet feeding direction.

A movable original document table 3 is driven to move in the directions indicated by arrows (a) and (b) in FIG. 2 by a bottom plate rising motor 105 (shown in FIG. 8). When the set filler 4 and the original document set sensor 5 detect the setting of the original documents 1, the movable original document table 3 rises in the direction indicated by the arrow (a) in FIG. 2 by the forward rotation of the bottom plate rising motor 105, and thereby the uppermost sheet surface of the original documents 1 contacts a sheet pick-up roller 7 functioning as a sheet pick-up device. The sheet pick-up roller 7 moves in the directions indicated by arrows (c) and (d) in FIG. 2 by a cam mechanism, while being driven by a pick-up motor 101 (shown in FIG. 8). When the movable table 3 rises, the sheet pick-up roller 7 is lifted in the direction indicated by the arrow (c) in FIG. 2 while being pressed by the top surface of the original documents 1 on the movable original document table 3. A table rising sensor 8 detects that the movable original document table 3 rises to a predetermined position. When the table rising sensor 8 detects the upper limit of the movable original document table 3, the bottom plate rising motor 105 is stopped, thereby stopping the sheet pick-up roller 7.

When an original document feeding signal is transmitted from the main body control unit 212 to the controller 100 via an interface after a start key of an operation unit 211 (shown in FIG. 8) of the main body 200 of the image reading apparatus 600 is pressed, the sheet pick-up roller 7 is driven to rotate by the forward rotation of a sheet feeding motor 102 functioning as a drive device (shown in FIG. 3), and thereby an uppermost sheet of the original documents 1 on the original document setting table 2 is picked up by the sheet pick-up roller 7. When the sheet pick-up roller 7 picks up an uppermost (first) sheet, the second or following sheets in the stacked original documents 1 may be fed together with the first sheet by the sheet pick-up roller 7 due to a frictional force and an electrostatic absorption between

the original documents 1. The rotation direction of the sheet pick-up roller 7 is equal to the sheet feeding direction.

Further, a sheet feeding belt 9 is driven to rotate in the sheet feeding direction by the forward rotation of the sheet feeding motor 102, and a reverse roller 10 is driven to rotate in the direction opposite to the sheet feeding direction. By these rotations of the sheet feeding belt 9 and the reverse roller 10, only the uppermost sheet of the original documents 1 is fed while separating the uppermost sheet from the other original documents 1. Specifically, the reverse roller 10 contacts the sheet feeding belt 9 with a predetermined pressure. When the reverse roller 10 is in direct contact with the sheet feeding belt 9 or in contact with the sheet feeding belt 9 via one sheet of the original document 1, the reverse roller 10 is rotated in a counter-clockwise direction by rotating the sheet feeding belt 9. When two or more sheets of the original documents 1 enter the nip part between the sheet feeding belt 9 and the reverse roller 10, the reverse roller 10 rotates in the clockwise direction (i.e., its original drive direction) by the action of a torque limiter (not shown), such that sheets other than the uppermost original document 1 are pushed back, thereby preventing the double-feeding of the original documents 1. Thus, the reverse roller 10 functions as an obstructing member that obstructs feeding of the second or following original documents 1 in the stacked original documents 1 other than the first (uppermost) original document 1. Hereinafter, the sheet feeding belt 9 and the reverse roller 10 may be referred to as a “sheet separating device”.

The original document 1, separated from the other original documents by the actions of the sheet feeding belt 9 and the reverse roller 10, is further fed by the sheet feeding belt 9, and the leading edge of the original document 1 is detected by a sheet abutment sensor 11. Further, the leading edge of the original document 1 is abutted against the nip part of pull-out rollers 12 in a halt condition. Subsequently, the original document 1 is conveyed by a predetermined distance, and thereby a leading edge portion of the original document 1 is

flexed. Under this condition, the drive of the sheet feeding belt 9 is stopped by stopping the sheet feeding motor 102. At this time, the sheet pick-up roller 7 moves away from the upper surface of the original document 1 while being driven by the pick-up motor 101. Therefore the original document 1 is fed only by the feeding force of the sheet feeding belt 9, and thereby the leading edge of the original document 1 enters the nip part of the pull-out rollers 12. As a result, the leading edge of the original document 1 is aligned, so that a sheet skew is corrected.

The pull-out rollers 12 have a function of conveying the aligned original document 1 to reverse rollers 14 in addition to the above-described sheet skew correcting function. Specifically, the pull-out rollers 12 are driven to rotate by the reverse rotation of the sheet feeding motor 102, thereby conveying the original document 1 to the reverse rollers 14. When the sheet feeding motor 102 is rotated in the reverse direction, the pull-out rollers 12 and the reverse rollers 14 are driven to rotate, but the sheet pick-up roller 7 and the sheet feeding belt 9 are not driven.

A plurality of original document width sensors 13 are arranged perpendicular to the sheet conveying direction to detect the width of the original document 1 while being conveyed between the pull-out rollers 12. The length of the original document 1 in the sheet conveying direction is detected based on motor pulses of the sheet feeding motor 102, by detecting the leading and trailing edges of the original document 1 via the sheet abutment sensor 11. When the original document 1 is conveyed from the registration section (C) to the reverse section (D) by driving the pull-out rollers 12 and the reverse rollers 14, the conveying speed of the original document 1 in the registration section (C) is set to be greater than that in the image reading/sheet conveying section (E). By doing so, the process time for conveying the original document 1 to the image reading/sheet conveying section (E) can be reduced.

When the leading edge of the original document 1 is detected by an entrance sensor 15, before the leading edge of the original document 1 enters the nip part between pair of reading entrance rollers 16, the conveying speed of the original document 1 is reduced to be equal to the image reading speed. Almost simultaneously, the reading entrance rollers 16, a roller 19, and outlet rollers 21 are driven by rotating an image reading motor 103 (shown in FIG. 4) in the forward direction.

Subsequently, when the leading edge of the original document 1 is detected by a registration sensor 17, an image reading device 201 is operated at an appropriate timing to read an image of the original document 1. When reading an image on one side of the original document 1, a lower reversing switch pick 23 and a dual sides switching pick 30 are in the positions indicated by the solid lines in FIG. 2. The original document 1, having passed through the image reading/sheet conveying section (E), is conveyed to the sheet stack section (J). At this time, when the leading edge of the original document 1 is detected by a sheet discharging sensor 22, a sheet discharging motor 104 (shown in FIG. 6) is driven to rotate in the forward direction, thereby rotating sheet discharging rollers 28 in the counter-clockwise direction. Further, by counting pulses of the sheet discharging motor 104 from the time when the sheet discharging sensor 22 detects the trailing edge of the original document 1, the driving speed of the sheet discharging motor 104 is reduced immediately before the trailing edge of the original document 1 passes through a nip part between the pair of sheet discharging rollers 28. Thus, the original document 1, discharged on a sheet discharging tray 29, is prevented from being pushed from or falling out of the sheet discharging tray 29.

In the main body 200 of the image reading apparatus 600, the image reading device 201 reads an image of an original document 1 by two types of image reading mechanisms. In one type of image reading mechanism, an image of an original document 1, which is placed on a platen glass 203, is read by moving an exposure lamp (not shown) and a first mirror (not

shown) in the horizontal direction, in FIG. 2, below the platen glass 203. In the other type of image reading mechanism, the exposure lamp and first mirror halt at an image reading position (i.e., an exposure position) below a slit glass 202. An image of an original document 1 conveyed in the auto document feeder 620 is read by the exposure lamp and the first mirror through the slit glass 202. The exposure lamp irradiates an image of an original document 1 with light, and the reflected light from the image of the original document 1 is led to an image reading element, such as a charge-coupled device (CCD) through the first mirror and lens (not shown, and imaged).

Next, drive systems of the image reading apparatus 600 according to embodiments of the present invention will be described by referring to FIGS. 3 through 7. FIG. 3 illustrates a drive system using the sheet feeding motor 102. FIG. 4 illustrates a drive system using the image reading motor 103. FIG. 5 illustrates a drive system using a lower reversing motor 106. FIG. 6 illustrates a drive system using the sheet discharging motor 104. FIG. 7 illustrates a drive system using an upper reversing motor 107.

In FIG. 3, the motor drive direction, when the original documents 1 are picked up by the sheet pick-up roller 7 and fed one by one by the operations of the sheet feeding belt 9 and the reverse roller 10 (hereafter “sheet separation operation”), is indicated by solid arrows. The motor drive direction, when the original documents 1 are conveyed by the pull-out rollers 12, the reverse rollers 14, and the relay rollers 33 (hereafter “sheet conveying operation”), is indicated by dotted arrows.

In the sheet separation operation, when the sheet feeding motor 102 is driven to rotate, the drive force of the sheet feeding motor 102 is transmitted from a pulley 301 to a gear 306, via a pulley 302 and a gear 305. The drive force transmitted from the gear 306 to a gear 307 causes the sheet feeding belt 9 to rotate. Further, the drive force transmitted from a gear 308 to a pulley 311, via a gear 309 and a gear/pulley 310, causes the sheet pick-up roller 7 to



rotate. The drive force transmitted from the gear 306 to a gear 314 causes the reverse roller 10 to rotate. A one-way clutch prevents transmission of the drive force to a gear pulley 303 coaxially provided to the gear 305, and to a gear 304 coaxially provided to the gear 314.

In the sheet conveying operation, when the sheet feeding motor 102 is driven to rotate, the drive force of the sheet feeding motor 102 is transmitted from the pulley 301 to the gear pulley 303, via the pulley 302. The drive force further transmitted from the gear pulley 303 to the gear 314 causes the reverse roller 10 to rotate. Further, the drive force transmitted from the gear pulley 303 to a pulley 313, via a pulley 312, causes the reverse rollers 14 to rotate. The drive force transmitted from the pulley 312 to a pulley 316, via a pulley 315 causes, the pull-out rollers 12 and relay rollers 33 to rotate. A one-way clutch prevents transmission of the drive force to the gear 305 coaxially provided to the gear pulley 303, and to the gear 314 coaxially provided to the gear 304. In this drive system using the sheet feeding motor 102, the sheet pick-up roller 7 and the sheet feeding belt 9 are efficiently driven by the same drive source. Therefore, the size of the apparatus can be reduced.

Referring to FIG. 4, when the image reading motor 103 is driven to rotate, the drive force of the image reading motor 103 is transmitted from a pulley 321 to a pulley 322. Further, the drive forces of the image reading motor 103 are transmitted from the pulley 322 to a pulley 324 and a pulley 326, thereby causing the reading entrance rollers 16 and the outlet rollers 21 to rotate. Further, the drive force of the image reading motor 103 is transmitted from the pulley 324 to a pulley 325, thereby rotating the roller 19.

Referring to FIG. 5, when the lower reversing motor 106 is driven to rotate, the drive force of the lower reversing motor 106 is transmitted from a pulley 344 to a pulley 346, via a pulley 345 thereby causing lower reversing rollers 25 and an auxiliary roller 27 to rotate.

Referring to FIG. 6, when the sheet discharging motor 104 is driven to rotate, the drive force of the sheet discharging motor 104 is transmitted from a pulley 341 to a pulley 343, thereby causing the sheet discharging rollers 28 to rotate.

Referring to FIG. 7, when the upper reversing motor 107 is driven to rotate, the drive force of the upper reversing motor 107 is transmitted from a pulley 347 to a pulley 348, thereby causing upper reversing rollers 31 to rotate..

FIG. 8 is a block diagram of a control system that controls the above-described sections (A) through (I). The main body 200 of the image reading apparatus 600 includes the main body control unit 212 that controls operations of the image reading apparatus 600. The main body control unit 212 receives signals transmitted from the auto document feeder 620 via a communication device (e.g., a serial communication line). The main body control unit 212 controls the drive of the image reading device 201 and the display of the operation unit 211 and a display unit 211a in accordance with received signals. The main body control unit 212 sends various types of control signals, such as operation mode signals and sheet feeding start signals, to the auto document feeder 620. The main body control unit 212 further controls the controller 100 to control sheet feeding and conveying operations of the auto document feeder 620.

The operation unit 211 includes various buttons (not shown), such as a start button, a reverse button, ten keys, and so forth, and the display unit 211a includes a liquid crystal display (LCD) panel. A user can set various operation modes and instruct the start and stop of operations of the apparatus via the operation unit 211.

The auto document feeder 620 includes the controller 100 that controls the sheet feeding and conveying operations of the auto document feeder 620. Various signals are input to the controller 100, such as detection signals sent from the above-described sensors 5, 8, 11, 13, 15, 17, 22, 34, and 35, and sensors 26, 32, 500 and 501 (described below), status signals

from the motors 101-107 in the drive system and from solenoids 110-112 (described below), and control signals, such as sheet feeding start signals sent from the main body 200. The controller 100 sends detection information from each sensor to the main body control unit 212 in the main body 200 of the image reading apparatus 600. Further, the controller 100 drives the motors 101-107 and the solenoids 110-112 in accordance with control signals sent from the main body control unit 212.

Each motor can be constructed as a stepping motor. Therefore, a drive amount of each motor is easily obtained by counting pulse numbers of the stepping motor and multiplying the counted pulse number by a drive amount per one pulse. Based on the calculated drive amount and information sent from each sensor, the length of the original document 1 is detected. Further, the control of a sheet conveyance interval between a preceding sheet and a succeeding sheet, the control of a sheet arrival timing at an image reading position after the registration sensor 17 detects the original document 1, and the control of image reading completion timing are performed.

The sheet feeding and conveying operations for original documents 1 when reading an image on one side of the original document 1 will be described. When the sheet abutment sensor 11 detects the trailing edge of a preceding original document 1, the sheet feeding motor 102 is stopped at a timing when the trailing edge of the preceding original document 1 passes through the nip part between the pull-out rollers 12. Then, the sheet feeding motor 102 is driven to rotate in the forward direction again, thereby starting a sheet feeding operation for a succeeding original document 1. At this time, although the drive of the reverse rollers 14 is stopped, the reverse rollers 14 are rotated because the timing pulley 313 includes a one-way clutch (not shown). The succeeding original document 1 fed by driving the sheet feeding motor 102 is on standby under the condition that the succeeding original document 1 is abutted against the nip part between the pull-out rollers 12. When the

preceding original document 1 reaches a predetermined position (in this embodiment, the leading edge of the preceding original document 1 reaches the position near the reading entrance roller 16 and its trailing edge passes the entrance sensor 15), the succeeding original document 1 is conveyed from the pull-out rollers 12 by driving the sheet feeding motor 102 to rotate in the reverse direction.

Next, sheet feeding and conveying operations for original documents 1 when reading images on dual sides of the original document 1 will be described referring to FIG. 2 and FIGS. 9A through 9J. The sheet feeding and conveying operations when reading an image on the first (front) side of an original document 1 are similar to the above-described sheet feeding and conveying operations when reading an image on only one side of an original document 1. However, the sheet feeding operation of a succeeding original document 1 is not performed during an operation of reading an image on the first side of a preceding original document 1. The succeeding original document 1 is set on the original document setting table 2 (shown in FIGS. 9A through 9E).

When the leading edge of the preceding original document 1 passes the registration sensor 17, the dual sides switching pick 30 moves in the direction from arrow (i) to arrow (j) in FIG. 2 by turning on the solenoid (SOL) 112 for driving the dual sides switching pick 30. Then, the image on the first side of the preceding original document 1 is read by the image reading device 201 in the image reading/sheet conveying section (E). Subsequently, the preceding original document 1 is conveyed from the lower reversing switch pick 23 toward the switch-back section (F) via the sheet discharging roller 28 and the dual sides switching pick 30 (shown in FIGS. 9B and 9C).

The sheet discharging motor 104 is driven to rotate in the forward direction at a timing when the leading edge of the preceding original document 1 passes the sheet discharging sensor 22, thereby rotating the sheet discharging rollers 28 in the counter-clockwise direction.

Almost simultaneously, the upper reversing rollers 31 are rotated in the counter-clockwise direction by driving the upper reversing motor 107 to rotate in the forward direction. When the sheet discharging sensor 22 detects the trailing edge of the preceding original document 1, each rotational speed of the sheet discharging motor 104 and the upper reversing motor 107 is increased to exceed the conveying speed of the preceding original document 1 in the image reading/sheet conveying section (E), and the image reading motor 103 is stopped. Further, after the sheet discharging sensor 22 detects the trailing edge of the preceding original document 1, the solenoid (SOL) 112 for driving the dual sides switching pick 30 is turned off or de-energized at a timing when the trailing edge of the preceding original document 1 passes through the nip part between the sheet discharging rollers 28. As a result, the dual sides switching pick 30 moves back in the direction from the arrow (j) to the arrow (i) in FIG. 2. Subsequently, when an upper reversing sensor 32 detects the trailing edge of the preceding original document 1, the upper reversing rollers 31 are switched to rotate in from the counter-clockwise direction to the clockwise direction by driving the upper reversing motor 107 to rotate in from the forward direction to the reverse direction. As a result, the upper reversing rollers 31 convey the preceding original document 1 in a switch-back direction (shown in FIG. 9D).

At this time, the relay rollers 33, the pull-out rollers 12, and the reverse rollers 14 are rotated in the sheet conveying direction by driving the sheet feeding motor 102 to rotate in the reverse direction. The preceding original document 1 is conveyed from the intermediate conveyance section (G) to the reverse section (D) via the registration section (C) again. When the entrance sensor 15 detects the leading edge of the preceding original document 1, the leading edge of the preceding original document 1 is abutted against the nip part of the reading entrance rollers 16 in a halt condition. Subsequently, the preceding original document 1 is conveyed by a predetermined distance, and thereby a leading edge portion of

the preceding original document 1 is flexed. Then, the sheet feeding motor 102 is stopped. As a result, the leading edge of the preceding original document 1 is aligned, so that a sheet skew is corrected.

Subsequently, the sheet feeding motor 102 is driven to rotate in the reverse direction again and the image reading motor 103 is driven to rotate in the forward direction, thereby conveying the preceding original document 1 to the image reading/sheet conveying section (E). When the registration sensor 17 detects the leading edge of the preceding original document 1, the solenoid (SOL) 110 for driving the lower reversing switch pick 23 is turned on or energized. As a result, the lower reversing switch pick 23 moves in the direction from arrow (f) to arrow (e) in FIG. 2.

Then, the image reading device 201 starts reading an image on the second (rear) side of the preceding original document 1. When the sheet discharging sensor 22 detects the leading edge of the preceding original document 1, the lower reversing rollers 25 are rotated in the counter-clockwise direction by driving the lower reversing motor 106 to rotate in the forward direction. Thus, the preceding original document 1 is directed to the switch-back section (H) while passing the lower portion of the lower reversing switch pick 23 (shown in FIG. 9F). When the sheet discharging sensor 22 detects the trailing edge of the preceding original document 1 after the image on its second (rear) side is read by the image reading device 201, the solenoid (SOL) 110 for driving the lower reversing switch pick 23 is turned off or de-energized, thereby moving back the lower reversing switch pick 23 in the direction from the arrow (e) to the arrow (f) in FIG. 2. Further, the lower reversing rollers 25 hold the trailing edge of the preceding original document 1 by stopping the lower reversing motor 106. As a result, the preceding original document 1 is temporarily held in the switch-back section (H) (shown in FIG. 9G).

Next, a sheet feeding and conveying operation for a succeeding original document 1 will be described. When the upper reversing sensor 32 detects the trailing edge of the preceding original document 1 during the preceding original document 1 is conveyed from the switch-back section (F) to the intermediate conveyance section (G) after the image on its first (front) side is read by the image reading device 201, the rotational direction of the sheet feeding motor 102 is switched from the reverse direction to the forward direction at a timing when the trailing edge of the preceding original document 1 passes through the nip part between the pull-out rollers 12. As a result, the feeding of a succeeding original document 1 is started. Subsequently, the leading edge of the succeeding original document 1 is aligned at the nip part of the pull-out rollers 12 in the registration section (C) (shown in FIG. 9F). Then, the succeeding original document 1 is conveyed to the image reading/sheet conveying section (E) via the reverse section (D). When the registration sensor 17 detects the leading edge of the succeeding original document 1, the dual sides switching pick 30 moves in the direction from the arrow (i) to the arrow (j) in FIG. 2. The succeeding original document 1 is conveyed to the switch-back section (F) via the outlet rollers 21, the lower reversing switch pick 23, the sheet discharging rollers 28, and the dual sides switching pick 30 while the image on its first (front) side is read by the image reading device 201 (shown in FIG. 9H). Then, the dual sides switching pick 30 moves back in the direction from the arrow (j) to the arrow (i) in FIG. 2.

Referring back to the preceding original document 1 temporarily held in the switch-back section (H), a lower reversing/sheet discharging switch pick 24 moves in the direction from arrow (h) to arrow (g) in FIG. 2 by turning on the solenoid (SOL) 111 for driving the lower reversing/sheet discharging switch pick 24 at a timing when the dual sides switching pick 30 moves back in the direction from the arrow (j) to the arrow (i) in FIG. 2. Further, the lower reversing rollers 25 and the auxiliary roller 27 rotate in the clockwise direction by driving the lower reversing motor 106 to rotate in the reverse direction, thereby conveying the

preceding original document 1 from the switch-back section (H) to the sheet stack section (J) via the sheet reversing/discharging section (I)(shown in FIG. 9I). The lower reversing/sheet discharging switch pick 24 moves back in the direction from the arrow (g) to the arrow (h) in FIG. 2 by turning off the solenoid (SOL) 111 for driving the lower reversing/sheet discharging switch pick 24 at a timing when the leading edge of the preceding original document 1 is conveyed into the nip part between the sheet discharging rollers 28.

When a lower reversing sensor 26 detects the trailing edge of the preceding original document 1, the driving speed of the sheet discharging motor 104 is decreased immediately before the trailing edge of the preceding original document 1 passes through the nip part between the sheet discharging rollers 28. Thus, the preceding original document 1 is prevented from being pushed from or falling out of the sheet discharging tray 29 (shown in FIG. 9J). The sheet conveying operation for the succeeding original document 1 when reading an image on the second (reverse) side of the document is performed in the same manner as that when reading the image on the first (front) side. The above-described sheet feeding and conveying operations for original documents 1 are repeated any desired number of times.

Next, sheet feeding control operation steps of the controller 100 according to an embodiment of the present invention will be described referring to FIG. 10.

When an original document feeding signal is transmitted from the main body control unit 212 to the controller 100 via an interface after a start key of the operation unit 211 of the main body 200 of the image reading apparatus 600 is pressed, the controller 100 causes the sheet feeding motor 102 to rotate in the forward direction. As described above, the sheet feeding belt 9 is driven to rotate in the sheet feeding direction by the forward rotation of the sheet feeding motor 102, and the reverse roller 10 is driven to rotate in the direction opposite to the sheet feeding direction. When two or more sheets of the original documents 1 enter the



nip part between the sheet feeding belt 9 and the reverse roller 10, the reverse roller 10 rotates in the clockwise direction such that sheets other than the uppermost original document 1 are pushed back, thereby preventing the double-feeding of the original documents 1.

An uppermost sheet of a stack of original documents 1 is picked up and fed to the sheet separating device (i.e., the sheet feeding belt 9 and the reverse roller 10) by rotating the sheet pick-up roller 7 in the forward direction. At this time, the rotational speed of the sheet feeding motor 102 is set to, for example, about 2300 pps (pulse per second). Because a sheet feeding amount per one pulse of the sheet feeding motor 102 is about 0.253 mm/pulse, the sheet feeding motor 102 rotates at a linear velocity of about 580 mm/second. The uppermost original document 1 of the stack of the original documents 1 is fed by the sheet pick-up roller 7 to the nip part between the sheet feeding belt 9 and the reverse roller 10. The uppermost original document 1 is separated from other original documents 1, which are fed together with the uppermost original document 1, by the actions of the sheet feeding belt 9 and the reverse roller 10. The other original documents 1 are pushed back by the reverse roller 10. The controller 100 determines if the original document 1 is adequately fed by the sheet pick-up roller 7 and the sheet feeding belt 9 to the sheet abutment sensor 11. Specifically, the controller 100 counts a pulse number of the sheet feeding motor 102, counted from when the sheet feeding motor 102 drives the sheet pick-up roller 7 to pick up the original document 1 (i.e., the start of a sheet feeding operation) to when the sheet abutment sensor 11 detects the leading edge of the fed original document 1. Alternatively, the controller 100 measures a time of the timer, measured from when the sheet feeding motor 102 drives the sheet pick-up roller 7 to pick up the original document 1 (i.e., the start of a sheet feeding operation) to when the sheet abutment sensor 11 detects the leading edge of the fed original document 1. The controller 100 determines whether the original document 1 slips by comparing the counted pulse number or the measured time with a predetermined threshold value. The predetermined

threshold value is obtained by calculating a theoretical number of pulses of the sheet feeding motor 102 when the original document 1 is fed without slipping in a span between the sheet pick-up roller 7 and the sheet abutment sensor 11. Alternatively, the predetermined threshold value is obtained by calculating a theoretical sheet feeding time during which the original document 1 is fed without slipping in the span.

If the original document 1 is a color original document, silicone oil is often applied onto the surface of the color original document. When the silicone oil adheres to the sheet pick-up roller 7 and the sheet feeding belt 9, sheet feeding forces of the sheet pick-up roller 7 and sheet feeding belt 9 decrease as the number of sheets fed by the sheet pick-up roller 7 and sheet feeding belt 9 increases. As a result, sheet feeding failures, such as a sheet slip and a sheet jam, typically occur. In this condition, the above-described counted pulse number or measured time exceeds a predetermined threshold value before the sheet abutment sensor 11 detects the leading edge of the original document 1. In this case, the controller 100 determines that a sheet jam caused by a sheet slip occurs. As described above, the occurrence of slip of the original document 1 increases if the balance is lost between the reverse force (sheet pushing back force) of the reverse roller 10 and the forward force (sheet feeding force) of the sheet feeding belt 9 and the sheet pick-up roller 7. In this embodiment, when the above-described counted pulse number or measured time exceeds a predetermined threshold value before the sheet abutment sensor 11 detects the leading edge of the original document 1, each rotational speed of the sheet pick-up roller 7, the sheet feeding belt 9, and the reverse roller 10 is decreased by decelerating the rotational speed of the sheet feeding motor 102. As a result, the balance is recovered between the sheet pushing back force of the reverse roller 10 and the sheet feeding force of the sheet feeding belt 9 and the sheet pick-up roller 7. By doing so, the original document 1 is fed at a lower sheet feeding speed by the sheet pick-up roller 7 and the sheet feeding belt 9 without slipping. As a result, a slip of the original

document 1 is avoided for being determined as a sheet jam, thereby preventing the stop of the sheet feeding operation of the auto document feeder 620.

FIG. 10 is flowcharts of the sheet feeding control operation steps of the controller 100 according to the embodiment of the present invention. First, the controller 100 powers the sheet feeding motor 102 and starts to supply pulse signals to the sheet feeding motor 102, thereby rotating the sheet feeding motor 102 in the forward direction in step S1. Subsequently, the controller 100 starts counting a pulse number of the sheet feeding motor 102 or starts a timer (not shown) in step S2. Then, the controller 100 determines if the sheet abutment sensor 11 detects a leading edge of an original document 1 in step S3. If the answer is NO in step S3, the controller 100 determines if the rotational speed of the sheet feeding motor 102 is a minimum speed in step S4.

If the answer is NO in step S4, the controller 100 determines if a pulse number “C” of the sheet feeding motor 102, counted from the start of a sheet feeding operation, or a time “T” of the timer measured from the start of a sheet feeding operation, exceeds a threshold value “V1” in step S5. The threshold value “V1” is obtained by calculating a theoretical number of pulses of the sheet feeding motor 102 when the original document 1 is fed without slipping in a span between the sheet pick-up roller 7 and the sheet abutment sensor 11. Alternatively, the threshold value “V1” is obtained by calculating a theoretical sheet feeding time during which the original document 1 is fed without slipping in the span. If the answer is YES in step S5, the rotational speed of the sheet feeding motor 102 is changed, for example, decreased from about 2300 pps to about 1500 pps, in step S6. When the rotational speed of the sheet feeding motor 102 is decreased from about 2300 pps to about 1500 pps, the rotational speed of the sheet feeding motor 102 is gradually decelerated. Alternatively, the sheet feeding motor 102 may be once stopped and be restarted to rotate at the rotational speed of about 1500 pps. These two methods of decreasing the rotational speed of the sheet feeding motor 102 will be

applied to all the embodiments described below. By changing each rotational speed of the sheet pick-up roller 7 and the sheet feeding belt 9 to a lower rotational speed, the decreased frictional forces between the sheet pick-up roller 7 and the original document 1 and between the sheet feeding belt 9 and the original document 1 can be effectively used, so that the feeding of the original document 1 can be enhanced.

Subsequently, the threshold value “V1” for comparison with the pulse number “C” or the time “T” is increased in step S7. Then, the sheet feeding control operation returns to re-execute step S3. If the rotational speed of the sheet feeding motor 102 is a minimum speed in step S4 (i.e., the answer is YES in step S4) and if the pulse number “C” of the sheet feeding motor 102 or the time “T” of the timer does not exceed the threshold value “V1” in step S5 (i.e., the answer is NO in step S5), the controller 100 determines if the pulse number “C” or the time “T” exceeds a threshold value “V2” that is significantly greater (greater by a predetermined amount) than the threshold value “V1” in step S8. If the answer is YES in step S8, the controller 100 determines that a sheet jam has occurred before the sheet abutment sensor 11 and stops the sheet feeding motor 102 in step S9. If the answer is NO in step S8, the sheet feeding control operation returns to re-execute step S3.

If the sheet abutment sensor 11 detects the leading edge of the original document 1 in step S3 (i.e., the answer is YES in step S3), the controller 100 sets a pulse number “P” of the sheet feeding motor 102 to feed the original document 1 from the sheet abutment sensor 11 to the nip part of the pull-out rollers 12 and necessary for abutting the original document 1 against the nip part of the pull-out rollers 12 in a halt condition for sheet skew correction in step S10.

As described above, even though the original document 1 slips in the sheet feeding operation due to the decreased sheet feeding force of the sheet pick-up roller 7 and/or the sheet feeding belt 9, the sheet feeding force of the sheet pick-up roller 7 and/or the sheet

feeding belt 9 can be recovered by decreasing the rotational speed of the sheet pick-up roller 7 and the sheet feeding belt 9. As a result, the original document 1 can be adequately fed at a lower speed without slipping. Thus, even though the productivity of the image forming apparatus decreases, the sheet feeding operation can be continued while decreasing a sheet feeding failure, such as a sheet slip and sheet jam, which stops the sheet feeding operation of the auto document feeder 620.

Sheet feeding control operation steps of the controller 100 according to another embodiment of the present invention will be described referring to FIGS. 11A, 11B, and 12. FIGS. 11A and 11B are flowcharts of sheet feeding control operation steps of the controller 100. In this embodiment, as illustrated in FIG. 12, a plurality of sensors, for example, two sensors (the sheet abutment sensor 11 and a first slip sensor 500) are disposed on a sheet feeding path between the sheet separating device (i.e., the sheet feeding belt 9 and the reverse roller 10) and the pull-out rollers 12. Because the decrease of the rotational speed of the sheet feeding motor 102 is preferably determined at an earlier stage to effectively enhance the feeding of the original document 1, the first slip sensor 500 is disposed immediately after a position where an uppermost original document 1 is separated from other original documents 1 by the sheet feeding belt 9 and the reverse roller 10.

Referring to FIGS. 11A and 11B, the sheet feeding control operation of the controller 100 will be described. First, the controller 100 powers the sheet feeding motor 102 and starts to supply pulse signals to the sheet feeding motor 102, thereby rotating the sheet feeding motor 102 in the forward direction in step S11. Subsequently, the controller 100 starts counting a pulse number of the sheet feeding motor 102 or starts a timer (not shown) in step S12. Then, the controller 100 determines if the first slip sensor 500 detects a leading edge of an original document 1 in step S13. If the answer is NO in step S13, the controller 100 determines if the rotational speed of the sheet feeding motor 102 is a minimum speed in step

S14. If the answer is NO in step S14, the controller 100 determines if a pulse number “C” of the sheet feeding motor 102, counted from the start of a sheet feeding operation, or a time “T” of the timer, measured from the start of a sheet feeding operation, exceeds a threshold value “V1” in step S15. The threshold value “V1” is obtained by calculating a theoretical number of pulses of the sheet feeding motor 102 when the original document 1 is fed without slipping in a span between the sheet pick-up roller 7 and the first slip sensor 500. Alternatively, the threshold value “V1” is obtained by calculating a theoretical sheet feeding time during which the original document 1 is fed without slipping in the span.

If the answer is YES in step 15, the rotational speed of the sheet feeding motor 102 is changed, for example, decreased from about 2300 pps to about 1500 pps, in step S16. When the rotational speed of the sheet feeding motor 102 is decreased from about 2300 pps to about 1500 pps, the rotational speed of the sheet feeding motor 102 is gradually decelerated. Alternatively, the sheet feeding motor 102 may be once stopped and be restarted to rotate at the rotational speed of about 1500 pps. Subsequently, the threshold value “V1” for comparison with the pulse number “C” or the time “T” is increased in step S17. Then, the sheet feeding control operation returns to re-execute step S13.

If the rotational speed of the sheet feeding motor 102 is a minimum speed in step S14 (i.e., the answer is YES in step S14) and if the pulse number “C” of the sheet feeding motor 102 or the time “T” of the timer does not exceed the threshold value “V1” in step S15 (i.e., the answer is NO in step S15), the controller 100 determines if the pulse number “C” or the time “T” exceeds a threshold value “V2” that is significantly greater (greater by a predetermined amount) than the threshold value “V1” in step S18. If the answer is YES in step S18, the controller 100 determines that a sheet jam has occurred before the first slip sensor 500 and stops the sheet feeding motor 102 in step S19. If the answer is NO in step S18, the sheet feeding control operation returns to re-execute step S13.

If the first slip sensor 500 detects the leading edge of the original document 1 in step S13 (i.e., the answer is YES in step S13), the controller 100 determines if the sheet abutment sensor 11 detects the leading edge of the original document 1 in step S20. If the answer is NO in step S20, the controller 100 determines if the pulse number “C” or the time “T” exceeds the threshold value “V2” in step S21. If the answer is YES in step S21, the controller 100 determines that a sheet jam has occurred before the sheet abutment sensor 11 and stops the sheet feeding motor 102 in step S22. If the answer is NO in step S21, the sheet feeding control operation returns to re-execute step S20.

If the sheet abutment sensor 11 detects the leading edge of the original document 1 in step S20 (i.e., the answer is YES in step S20), the controller 100 sets a pulse number “P” of the sheet feeding motor 102 to feed the original document 1 from the sheet abutment sensor 11 to the nip part of the pull-out rollers 12 and for abutting the original document 1 against the nip part of the pull-out rollers 12 in a halt condition for sheet skew correction in step S23.

As seen from the flowcharts of sheet feeding control operation steps of the controller 100 in FIGS. 11A and 11B, when the rotational speed of the sheet feeding motor 102 is decreased before the original document 1 reaches the first slip sensor 500, it is not necessary to decrease the rotational speed of the sheet feeding motor 102 again if the sheet abutment sensor 11 does not detect the leading edge of the original document 1. This is because the sheet separating device (i.e., the sheet feeding belt 9 and the reverse roller 10) is not located between the first slip sensor 500 and the sheet abutment sensor 11.

FIG. 13A is a schematic view of a portion of the auto document feeder 620 according to another embodiment of the present invention. In the auto document feeder 620 of FIG. 13A, as compared to the auto document feeder 620 of FIG. 12, the first slip sensor 500 is disposed upstream of the sheet separating device (i.e., the sheet feeding belt 9 and the reverse roller 10) in the sheet feeding direction instead of downstream of the sheet separating device.

If a user of the image forming apparatus does not set a stack of original documents 1 on the original document setting table 2 including the movable original document table 3 (i.e., the user sets the original documents 1 one by one on the original document setting table 2) or if the user uses heavy-mass original documents 1 that are not double-fed, the first slip sensor 500 may be disposed upstream of the sheet separating device in the sheet feeding direction. In this configuration, the slip of the original document 1 due to the misfeeding of the sheet pick-up roller 7 can be efficiently detected based on the detection result of the first slip sensor 500. In this embodiment the control of a sheet feeding operation is similarly performed as shown in the flowcharts of FIGS. 11A and 11B. When the slip of the original document 1 occurs due to the misfeeding of the sheet pick-up roller 7, the rotational speed of the sheet feeding motor 102 is decreased, thereby decreasing the rotational speed of the sheet pick-up roller 7. By doing so, the grip force of the sheet pick-up roller 7 increases, thereby enhancing the feeding of the original document 1. As a result, a slip of the original document 1 can be avoided for being determined as a sheet jam.

FIG. 13B is a schematic perspective view of a portion of the auto document feeder 620 of FIG. 13A showing a position of the sheet pick-up roller 7, and FIG. 13C is a schematic perspective view of a portion of the auto document feeder 620 of FIG. 13A showing positions of the first slip sensor 500 and the reverse roller 10. FIGS. 13B and 13C show a positional relationship between the first slip sensor 500, the sheet pick-up roller 7, and the reverse roller 10.

Next, sheet feeding control operation steps of the controller 100 according to another embodiment of the present invention will be described referring to FIGS. 14A, 14B, 14C, and 15. FIGS. 14A through 14C are flowcharts of sheet feeding control operation steps of the controller 100. FIG. 15 is a schematic view of a portion of the auto document feeder 620 according to another embodiment of the present invention. In the auto document feeder 620



of FIG. 15, as compared to the auto document feeder 620 of FIG. 13A, a second slip sensor 501 is disposed downstream of the sheet separating device (i.e., the sheet feeding belt 9 and the reverse roller 10) in the sheet feeding direction in addition to the first slip sensor 500 disposed upstream of the sheet separating device. If a plurality of the second slip sensors 501 are disposed on the sheet feeding path between the sheet separating device and the sheet abutment sensor 11, the slip and jam of the original document 1 can be efficiently detected. Although two slip sensors 500 and 501 are disposed in this embodiment, the number of the slip sensors is not limited to two.

Referring to FIGS. 14A through 14C, the sheet feeding control operation of the controller 100 will be described. The sheet feeding control operation steps S31 through S39 in FIG. 14A are similar to the sheet feeding control operation steps S11 through S19 in FIGS. 11A and 11B. Therefore, their descriptions are omitted here. In steps S35 and S38 in FIG. 14A, a pulse number of the sheet feeding motor 102, counted from the start of a sheet feeding operation, is designated by a reference character “C1”, and a time of a timer, measured from the start of a sheet feeding operation, is designated by a reference character “T1”.

In step S40, the controller 100 clears the counted pulse number “C1” of the sheet feeding motor 102 or the measured time “T1” of the timer, and restarts counting a pulse number of the sheet feeding motor 102 or restarts a timer (not shown). Then, the controller 100 determines if the second slip sensor 501 detects the leading edge of the original document 1 in step S41.

If the answer is NO in step S41, the controller 100 determines if the rotational speed of the sheet feeding motor 102 is a minimum speed in step S42. If the answer is NO in step S42, the controller 100 determines if a pulse number “C2” of the sheet feeding motor 102 or a time “T2” of the timer, counted or measured from when the first slip sensor 500 detects the leading edge of the original document 1, exceeds a threshold value “V3” in step S43. The

threshold value “V3” is obtained by calculating a theoretical number of pulses of the sheet feeding motor 102 when the original document 1 is fed without slipping in a span between the first slip sensor 500 and the second slip sensor 501. Alternatively, the threshold value “V3” is obtained by calculating a theoretical sheet feeding time during which the original document 1 is fed without slipping in the span.

If the answer is YES in step 43, the rotational speed of the sheet feeding motor 102 is decreased in step S44. Subsequently, the threshold value “V3” for comparison with the pulse number “C2” or the time “T2” is increased in step S45. Then, the sheet feeding control operation returns to re-execute step S41.

If the rotational speed of the sheet feeding motor 102 is a minimum speed in step S42 (i.e., the answer is YES in step S42) and if the pulse number “C2” of the sheet feeding motor 102 or the time “T2” of the timer does not exceed the threshold value “V3” in step S43 (i.e., the answer is NO in step S43), the controller 100 determines if the pulse number “C2” or the time “T2” exceeds a threshold value “V4” that is significantly greater (greater by a predetermined amount) than the threshold value “V3” in step S46. If the answer is YES in step S46, the controller 100 determines that a sheet jam has occurred before the second slip sensor 501 and stops the sheet feeding motor 102 in step S47. If the answer is NO in step S46, the sheet feeding control operation returns to re-execute step S41.

If the second slip sensor 501 detects the leading edge of the original document 1 in step S41 (i.e., the answer is YES in step S41), the controller 100 determines if the sheet abutment sensor 11 detects the leading edge of the original document 1 in step S48. If the answer is NO in step S48, the controller 100 determines if the pulse number “C2” or the time “T2” exceeds the threshold value “V4” in step S49. If the answer is YES in step S49, the controller 100 determines that a sheet jam has occurred before the sheet abutment sensor 11

and stops the sheet feeding motor 102 in step S50. If the answer is NO in step S49, the sheet feeding control operation returns to re-execute step S48.

If the sheet abutment sensor 11 detects the leading edge of the original document 1 in step S48 (i.e., the answer is YES in step S48), the controller 100 sets a pulse number “P” of the sheet feeding motor 102 to feed the original document 1 from the sheet abutment sensor 11 to the nip part of the pull-out rollers 12 and for abutting the original document 1 against the nip part of the pull-out rollers 12 in a halt condition for sheet skew correction in step S51.

In this embodiment, the slip of the original document 1 due to the misfeeding of the sheet pick-up roller 7 and an occurrence of a sheet jam in the span between the sheet pick-up roller 7 and the first slip sensor 500 can be efficiently detected by comparing the counted pulse number “C1” or the measured time “T1” with the threshold value. Further, by decreasing the rotational speed of the sheet feeding motor 102, the grip force of the sheet pick-up roller 7 increases, thereby enhancing the feeding of the original document 1. Even though the original document 1 reaches the first slip sensor 500 within the threshold value “V1”, the original document 1 may slip under the influence of the sheet pushing back force (i.e., the force obstructing the feeding of the original document 1) of the reverse roller 10. In this embodiment the slip of the original document 1 due to the misfeeding of the sheet feeding belt 9 and an occurrence of a sheet jam in the span between the first slip sensor 500 and the second slip sensor 501 can be efficiently detected by comparing the counted pulse number “C2” or the measured time “T2” with the threshold value. Further, by decreasing the rotational speed of the sheet feeding motor 102, the balance recovers between the sheet pushing back force of the reverse roller 10 and the sheet feeding force of the sheet feeding belt 9 and the sheet pick-up roller 7. As a result, the feeding of the original document 1 is enhanced. Thus, in this embodiment, the occurrence of slip of the original document 1 can be

detected at an early stage. Further, a slip of the original document 1 can be prevented from being determined as a sheet jam.

Sheet feeding control operation steps of the controller 100 according to another embodiment of the present invention will be described referring to FIGS. 2, 16A and 16B. FIGS. 16A and 16B are flowcharts of the sheet feeding control operation steps of the controller 100. The sheet feeding control operation steps of the controller 100 in FIGS. 16A and 16B are similar to those in FIG. 10 except for steps S66 through S69. Therefore, the sheet feeding control operations steps S66 through S69 will be mainly described here.

If a pulse number “C” of the sheet feeding motor 102, counted from the start of a sheet feeding operation, or a time “T” of the timer, measured from the start of a sheet feeding operation, exceeds a threshold value “V1” in step S65, the controller 100 determines if the rotational speed of the sheet feeding motor 102 has been changed before in step S66. If the answer is NO in step S66, the rotational speed of the sheet feeding motor 102 is changed, for example, decreased from about 2300 pps to about 1500 pps, in step S67. Subsequently, the threshold value “V1” for comparison with the pulse number “C” or the time “T” is increased in step S68. Then, the sheet feeding control operation returns to re-execute step S63.

If the rotational speed of the sheet feeding motor 102 has been changed in step S66 (i.e., the answer is YES in step S66), the rotational speed of the sheet feeding motor 102 is decreased to a minimum speed, for example, from about 1500 pps to about 1000 pps, in step S69.

Sheet feeding control operation steps of the controller 100 according to another embodiment of the present invention will be described referring to FIGS. 15, 17A, 17B, and 17C. FIGS. 17A through 17C are flowcharts of sheet feeding control operation steps of the controller 100. In this embodiment, as illustrated in FIG. 15, the first slip sensor 500 and the

second slip sensor 501 are disposed upstream and downstream of the sheet separating device in the sheet feeding direction, respectively.

The sheet feeding control operation steps S81 through S89 in FIG. 17A are similar to the sheet feeding control operation steps S31 through S39 in FIG. 14A. Therefore, their descriptions are omitted here. If the first slip sensor 500 detects the leading edge of the original document 1 in step S83 (i.e., the answer is YES in step S83), the controller 100 calculates a slip ratio “R1” of the original document 1 fed in the sheet feeding path between the sheet pick-up roller 7 and the first slip sensor 500, and buffers the calculated slip ratio “R1” in step S90. The slip ratio “R1” is obtained by dividing an actual (counted) pulse number “C1” by a threshold pulse number “V1” or by dividing an actual (measured) time “T1” by a threshold time “V1”. Then, the controller 100 clears the counted pulse number “C1” of the sheet feeding motor 102 or the measured time “T1” of the timer, and restarts counting a pulse number of the sheet feeding motor 102 or restarts a timer (not shown) in step S91. Then, the controller 100 determines if the second slip sensor 501 detects the leading edge of the original document 1 in step S92. Then, the sheet feeding control operation steps S93 through S98 in FIG. 17A are performed similarly as in steps S41 through S46 in FIG. 14A.

If the second slip sensor 501 detects the leading edge of the original document 1 in step S92 (i.e., the answer is YES in step S92), the controller 100 calculates a slip ratio “R2” of the original document 1 fed in the sheet feeding path between the first slip sensor 500 and the second slip sensor 501, and buffers the calculated slip ratio “R2” in step S99. The slip ratio “R2” is obtained by dividing an actual (counted) pulse number “C2” by a threshold pulse number “V3” or by dividing an actual (measured) time “T2” by a threshold time “V3”. Then, the controller 100 compares the slip ratio “R1” with the slip ratio “R2”, and determines if the slip ratio “R1” exceeds the slip ratio “R2” in step S100. If the answer is YES in step

S100, the controller 100 determines if the rotational speed of the sheet feeding motor 102 has been changed before in step S101. If the answer is YES in step S101, the decreased rotational speed of the sheet feeding motor 102 (e.g., 1500 pps) is returned to its original rotational speed (e.g., 2300 pps) in step 102. If the answer is NO in step S100, the sheet feeding control operation proceeds to step S103. Then, the controller 100 determines if the sheet abutment sensor 11 detects the leading edge of the original document 1 in step S103. The sheet feeding control operation steps S104 through S106 in FIG. 17B are performed similarly as in steps S49 through S51 in FIG. 14B.

In the above-described embodiment, if the slip ratio “R1” exceeds the slip ratio “R2”, the sheet slip has occurred at the sheet pick-up roller 7 rather than the sheet feeding belt 9. In this case, if the rotational speed of the sheet feeding motor 102 has been decreased before the second slip sensor 501 detects the leading edge of the original document 1, the decreased rotational speed of the sheet feeding motor 102 is returned to its original rotation speed. By doing so, the sheet feeding speed is increased after the second slip sensor 501 detects the leading edge of the original document 1, so that the decrease of the productivity of the image forming apparatus due to the low sheet feeding speed can be minimized.

In the above-described flowcharts of FIGS. 17A and 17B, the step S90 may be replaced by a flowchart illustrated in FIG. 18A, and the step S99 may be replaced by a flowchart illustrated in FIG. 18B. FIGS. 18A and 18B are flowcharts for displaying a replacement message for the sheet pick-up roller 7 and/or the sheet feeding belt 9 when the above-described slip ratio “R1” and/or slip ratio “R2” exceed a threshold value.

Referring to FIG. 18A, the controller 100 calculates the slip ratio “R1” of the original document 1 fed in the sheet feeding path between the sheet pick-up roller 7 and the first slip sensor 500, and buffers the calculated slip ratio “R1” in step S90a. Then, the controller 100 determines if a slip of an original document 1 has occurred by comparing the slip ratio “R1”

with a threshold value in step S90b. Specifically, if the slip ratio “R1” exceeds the threshold value, the controller 100 determines that the slip of the original document 1 has occurred. If the answer is YES in step S90b, as illustrated in FIG. 19, a message (for example “sheet pick-up roller needs to be replaced with a new sheet pick-up roller please contact a service man”) is displayed on the display unit 211a in the main body 200 of the image reading apparatus 600 in step S90e. Such a message may be displayed on the auto document feeder 620 instead of the main body 200 of the image reading apparatus 600. Further, an operator may be notified of the necessity for the replacement of the sheet pick-up roller 7 by turning on or flashing a light instead of displaying a message. If the answer is NO in step S90b, the above-described message is not displayed on the display unit 211a.

Steps 90c, 90d, and 90f illustrated by dotted lines in FIG. 18A are for optional operations. Specifically, if the controller 100 determines that the slip of the original document 1 has occurred in step S90b, a slip counter (not shown) is incremented by one in step S90c. Then, the controller 100 determines if the number of the slip counter is 2 or greater in step S90d. If the answer is YES in step S90d, the above-described message is displayed on the display unit 211a in step S90e.

If the answer is NO in step S90d, the above-described message is not displayed on the display unit 211a. If the controller 100 determines that the slip of the original document 1 has occurred in step S90b (i.e., the answer is NO in step S90b), the slip counter is set to zero in step S90f. Thus, in the optional operations, if the slip of the original document 1 has consecutively occurred at least two times, the above-described message is displayed on the display unit 211a. By doing so, the message regarding the necessity of the replacement of the sheet pick-up roller 7 becomes more reliable. Further, an unnecessary message displayed, for example, when stapled original documents 1 are erroneously set on the original document setting table 2 and jammed, can be avoided.

The operations in the flowchart of the FIG. 18B are similar to those in FIG. 18A. In FIG. 18B, the controller 100 calculates the slip ratio “R2” of the original document 1 fed in the sheet feeding path between the first slip sensor 500 and the second slip sensor 501, and buffers the calculated slip ratio “R2” in step S99a. Then, the controller 100 determines if a slip of an original document 1 has occurred by comparing the slip ratio “R2” with a threshold value in step S99b. If the answer is YES in step S99b, as illustrated in FIG. 19, a message (for example “sheet feeding belt needs to be replaced with a new sheet feeding belt, please contact a service man”) is displayed on the display unit 211a in the main body 200 of the image reading apparatus 600 in step S99e.

In the above-described embodiment of the present invention, when the controller 100 determines that a sheet jam has occurred, a message (for example “sheet jam has occurred”) may be displayed on the display unit 211a.

According to the embodiments of the present invention, when a sheet slip occurs due to the decrease of a sheet feeding force of the sheet pick-up roller 7 and/or the sheet feeding belt 9, the sheet feeding force of the sheet pick-up roller 7 and/or the sheet feeding belt 9 is restored by decreasing the rotational speed of the sheet pick-up roller 7 and/or the sheet feeding belt 9. In a background sheet feeding device, a sheet slip was determined as an occurrence of sheet jam, and a sheet feeding operation of the sheet feeding device was stopped based on such a determination. In the sheet feeding device according to the embodiments of the present invention, a sheet slip caused by the misfeeding of the sheet pick-up roller 7 and/or the sheet feeding belt 9 can be decreased by decreasing the rotational speed of the sheet pick-up roller 7 and/or the sheet feeding belt 9. Thus, stopping of the sheet feeding operation of the sheet feeding device based on the determination of an occurrence of sheet jam can be prevented.



In the above-described embodiment, the controller 100 may control the sheet feeding operation by counting the pulse number of the sheet feeding motor 102. As compared to the control of the sheet feeding operation by using a timer to measure a sheet feeding time of the sheet feeding motor 102, the controller 100 can efficiently control the sheet feeding operation (e.g., without necessity of software processing) even if a sheet feeding speed is changed.

The control of the sheet feeding operation by using a timer to measure a sheet feeding time of a sheet feeding motor may be effective in an auto document feeder that does not use a stepping motor.

The present invention has been described with respect to the exemplary embodiments illustrated in the figures. However, the present invention is not limited to these embodiments and may be practiced otherwise.

As an alternative to controlling sheet feeding by counting the pulse number of the sheet feeding motor 102, sheet feeding can be controlled by using an encoder provided on each roller shaft for the sheet pick-up roller 7 and the sheet feeding belt 9.

In the above-described embodiments, the sheet pick-up roller 7 and the sheet feeding belt 9 are driven to rotate by the sheet feeding motor 102. Alternatively, the sheet pick-up roller 7 and the sheet feeding belt 9 may be driven to rotate by separate motors. In this case, the sheet pick-up roller 7 and the sheet feeding belt 9 may be controlled to be rotated at their own optimum speeds.

The present invention has been described with respect to an auto document feeder for use in an image reading apparatus and an image forming apparatus. However, the present invention may be applied to any type of sheet material feeding device. Further, the exemplary image forming apparatus illustrated in FIG. 1 is a copying machine. However, the image forming apparatus may be a facsimile machine, a printer, a multifunctional image forming apparatus, or other similar image forming apparatuses.

Numerous additional modifications and variations of the present invention are possible in light of the above teachings. It is therefore understood that within the scope of the appended claims, the present invention may be practiced other than as specifically described herein.